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X63-11434
Code 2d
NASA TT F-8351

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON February 1963

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CONDUCTIVITY MEASUREMENTS ON GAS JETS

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In solving any problem in magnetogasdynamics, it is necessary to know the electric conductivity of the gas under investigation. For real gas mixtures, however, which frequently are not in thermodynamic equilibrium, the theoretical determination of this quantity is very difficult. Presently available experimental data on the conductivity of heated gases are completely inadequate. /1095

This article is devoted to a description of an induction method of measuring the electric conductivity of gas jets and to various measurements in streams of heated gas.

The main advantage of the induction method of investigating a plasma is the possibility of working with weak high-frequency fields, which do not appreciably disturb the plasma investigated. Moreover, these measurements do not require any device to be introduced into the space occupied by the plasma.

The present method is based on the measurement of the parameters of a tank circuit, the coil of which encloses the jet of heated gas. We used a cylindrical coil and a jet of circular cross section, disposed about a common axis; accordingly, the subsequent discussion refers to this particular arrangement. If the size and relative positions of the coil and the plasma jet are fixed, the circuit parameters (inductance L, resistance R, and Q factor) depend on the value and distribution of the electric conductivity with respect to the cross section of the jet, and, moreover, on the frequency of the current supplied to the circuit. (The permeability of the jet is assumed equal to unity.) By measuring the circuit parameters for different dimensions of the coil and jet at different frequencies, it is possible to determine the value and distribution of the conductivity with respect to the cross section of the jet, by means either of appropriate calculations or of calibration curves. In measurements on jets in which the conductivity may be assumed constant over the cross section, it is sufficient to measure just one of the parameters at a single frequency. In our experiments we measured the Q factor of the circuit. The choice of frequency is conditioned by considerations relating to an adequate sensitivity of the circuit. The current frequency ensuring a sufficiently sensitive circuit can be found from the following relation

$$f \approx \frac{2.5 \cdot 10^8}{d^2 \sigma},$$

where d = diameter of jet (cm); σ = conductivity of jet (1/ohm·cm).

The expression is obtained from the condition $d/\Delta \approx 3.5$, where Δ = depth of current penetration into the plasma jet. If the conductivity varies over the cross section of the jet and it is necessary to measure its averaged value, then the ratio should be taken as less than 3.5, but in this case the sensitivity of the system will be somewhat less. The sensitivity of the system falls markedly with increase in the gap between the coil and the surface of the jet. Therefore this gap should be reduced to a minimum. In order to /1096 protect the circuit parameters from the influence of nearby conductors, the elements of the circuit should be shielded.

Measuring Circuit

The Q factor of the circuit can be measured by means of an ordinary Q-meter, one of the UK-1 type for example, or by means of another radio circuit. We used the circuit shown in Fig. 1.

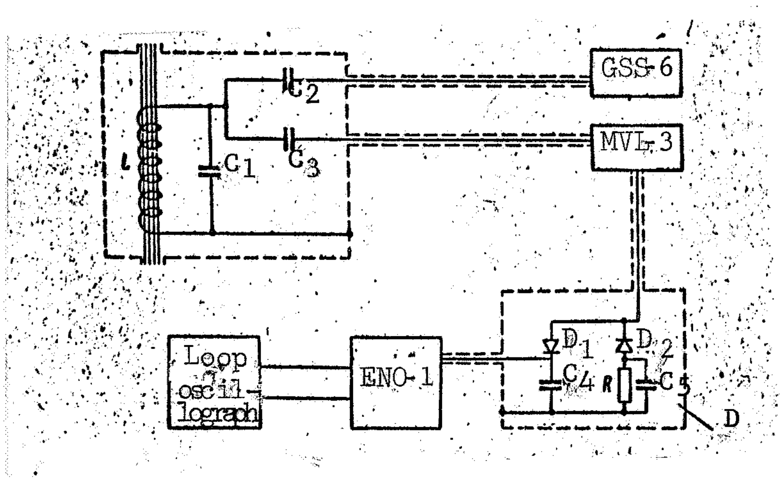

Fig. 1

The design of the shielded coil and its basic dimensions are shown in Fig. 2. The circuit capacitor C_1 and the coupling capacitors C_2, C_3 are located inside a separate shield 8, fastened to the shield 1,6 of coil 3, which at the same time serves as the body of the instrument. The coil is protected and kept clean by means of a quartz tube 4, closed with a flange 2. The coil leads are insulated from the body by means of bushings 5.

Shield 8 not shown

View in direction of arrow A, turned through 90°

Cover of shield 8 removed

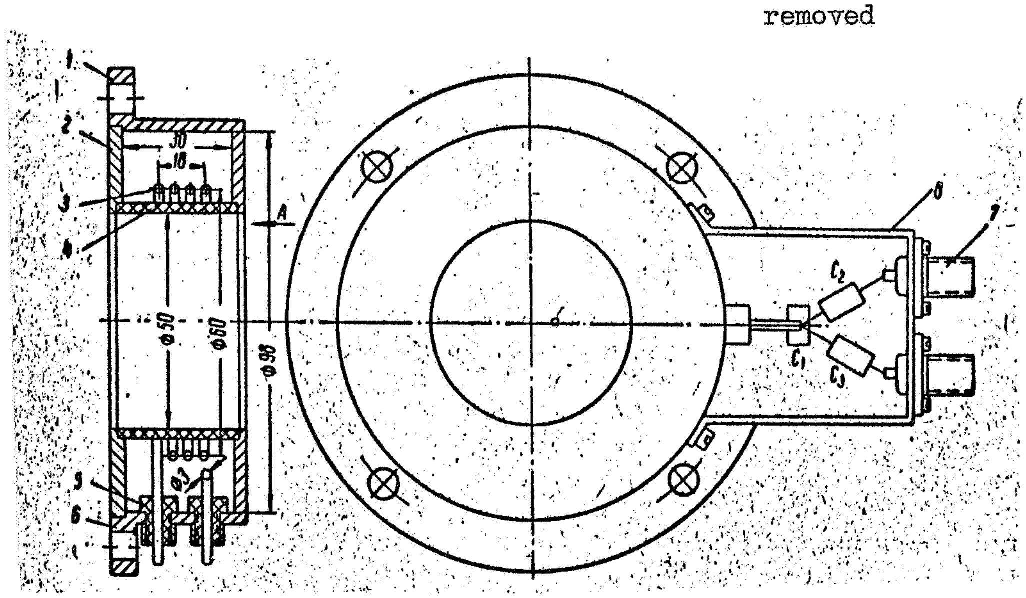

Fig. 2

The device is connected with the other elements of the circuit of a coaxial cable plugged in at 7. /1097

The circuit is supplied by a GSS-6 standard signal generator. The signal from the circuit is received by the h-f amplifier of an MVL-3 tube millivoltmeter, which was also used for visual read-out of the signal attenuation when the plasma jet was introduced into the coil. For recording purposes, the signal was fed from the h-f amplifier to a detector D (Fig. 1), amplified, and recorded by means of a loop oscillograph. The detector is based on two D 2-D type semiconductor diodes; the resistance R is equal to the input resistance of the amplifier, the vertical sweep amplifier of the ENO-1 oscillograph.

The circuit was calibrated with the aid of electrolytes placed in cylindrical vessels with an inside diameter equal to the diameter of the jet. Fig. 3 shows the calibration curve for our particular case.

d of jet = 40 mm; f = 13.1 mc.

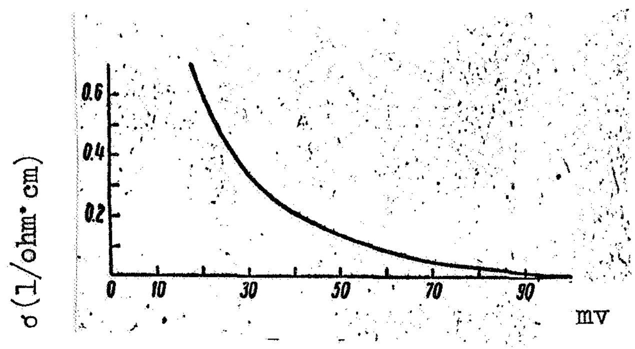

Fig. 3.

Description of Experiment

The system is brought into the working position, and the frequency and voltage to be supplied by the GSS-6 generator are selected. The resonant frequency is determined with respect to the maximum voltage, measured by the millivoltmeter, whereupon the indicator of the millivoltmeter is set to the "zero" position (100 mv graduation). In order to prevent detuning of the circuit owing to changes in temperature during the measuring period, the coil is water-cooled. The water is fed in at a slight overpressure (about 1-2 atm) and forms a free jet.

Nitrogen introduced into the housing prevents the penetration of vapors and also serves to cool the quartz tube and the coil. The quartz tube, moreover, in the course of testing, is washed with atmospheric air for ejection purposes.

The system is now ready to receive the jet of heated gas; the desired jet parameters are selected, the frequency of the GSS-6 generator is adjusted (with respect to the maximum voltage at the

MVL-3 millivoltmeter), and readings are taken and simultaneously recorded at the loop oscillograph.

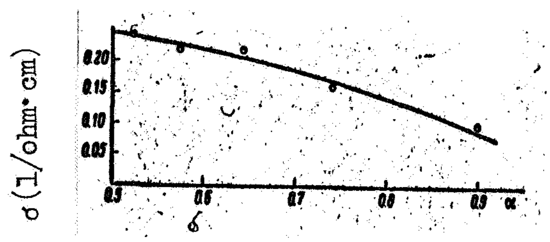

Fig. 4.

In order to check the working of the circuit, we used a jet obtained by burning ethyl alcohol and 0.01% potassium in oxygen. The pressure in the combustion chamber was maintained at four atmospheres. The jet was sustained for 6 to 12 seconds. The calibration of the circuit was checked through three or four experiments and no significant variations were observed. The results of conductivity measurements on a gas jet are given in Fig. 4, where the degree of oxidation α (α = 1 for complete combustion of the alcohol) is plotted along the abscissa, and the conductivity in the jet σ along the ordinate axis. /1098

Fig. 5 shows a typical oscillogram obtained in the course of these experiments. It is divided into four sections: I - adjustment of jet parameters; II - tuning circuit; III - jet and measuring circuit in steady state; IV - jet cut-off.

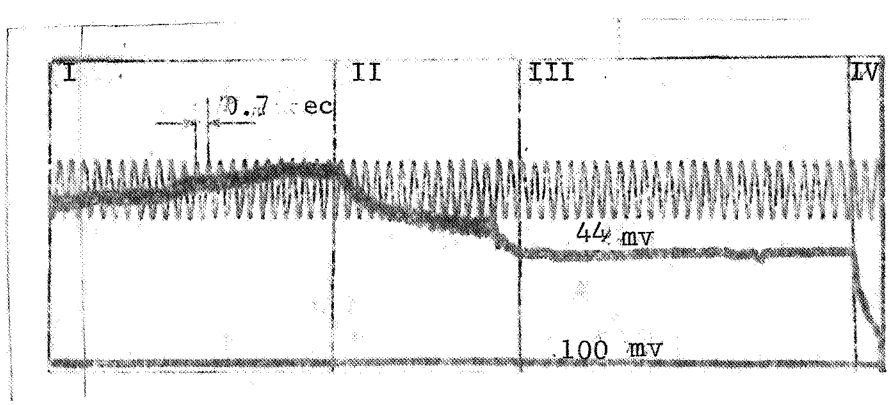

Fig. 5.

Although these results are preliminary, there is reason to believe that the method proposed will be useful for investigating the dependence of conductivity on the parameters of a jet of heated gas.

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Rec'd: 3 September 1961.

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